# The Application and Impact of 6G Networks on Navigation and Autonomous Driving Systems

Haojie Huang *

University of Bristol, Bristol BS8 1QU, British

* Corresponding Author Email: rn24711@bristol.ac.uk

**Abstract.** The evolution of the sixth-generation(6G) network is expected to bring about transformative changes to navigation and autonomous driving systems. Unlike 5G, which laid the foundation for early vehicle-to-Everything (V2X) applications, 6G will achieve breakthroughs in transmission speed, latency, and connection density. By integrating artificial intelligence, edge computing, and satellite communication, 6G lays the technical foundation for achieving centimeter-level positioning and nearly instantaneous data exchange between vehicles and roads. These capabilities will enhance the safety of autonomous driving decisions, optimize traffic coordination, and support advanced applications such as collaborative driving and large-scale fleet management in smart cities. Meanwhile, the impact of 6G networks is extending to broader social goals, covering areas such as energy efficiency, environmental sustainability, and resilient urban planning. Despite its vast potential, challenges such as deployment costs, standardization, and data security still exist. Overall, 6G is expected to redefine intelligent mobility by combining unprecedented connectivity capabilities with smart control. However, its success still requires continuous innovation and global collaboration to drive it forward together.

**Keywords:** 6G Networks, Autonomous Driving Systems, Vehicle-to-Everything.

## 1. Introduction

The approach of 6G networks heralds a new leap in wireless communication, with its data transmission rate expected to increase by several orders of magnitude compared to existing systems. 6G is characterized by ultra-low latency and ultra-high connection density, and places greater emphasis on integrating artificial intelligence (AI), edge computing, and massive sensor networks into a unified platform. These breakthroughs have created transformative opportunities for industries that rely on real-time data processing, precise positioning, and seamless connection, allowing wireless communication to extend far beyond traditional boundaries.

From the perspective of intelligent transportation and autonomous driving, the significance of this upgrade is particularly profound. At present, self-driving cars are still constrained by the limitations of network speed, reliability, and coverage, which may simultaneously affect safety and efficiency. For instance, signal weakening in tunnels or dense urban canyons often leads to positioning errors, while delays or interruptions in vehicle networking communications may hinder timely decision-making. Although 5G technology has laid an essential foundation by supporting initial vehicle networking applications, it still fails to meet the strict requirements for fully autonomous driving.

In contrast, 6G promises reliable and ultra-low latency communication, combined with centimeter-level positioning accuracy, marking a transformative leap in technological development. Vehicles equipped with 6G capabilities can not only connect with surrounding infrastructure but also directly exchange information in real time. This high degree of interconnection supports safer and faster decision-making, optimizing route planning and improving traffic management efficiency. It has also given rise to new application scenarios such as collaborative control, highway platoons, and dynamic traffic optimization - all of which require millisecond-level precise coordination.

Beyond the individual vehicle level, 6G is expected to drive the convergence of satellite navigation systems with AI-enabled V2X networks, forming the backbone of intelligent transportation systems. Such convergence will enable dynamic traffic flow management across entire urban areas, reduce accidents through predictive analytics, and support the deployment of fully autonomous fleets in smart cities. The implications of these systemic transformations extend far beyond road safety and mobility efficiency, reaching into energy consumption, environmental sustainability, and the long-term design of urban infrastructure.

As the foundational technology for next-generation positioning and connectivity, 6G leverages satellite navigation systems and artificial intelligence to enhance real-time communication and autonomous decision-making capabilities. The upgraded intelligent transport systems will comprehensively reduce traffic accidents, profoundly impacting fully autonomous driving within cities and thereby further shaping the landscape of automated urban mobility. However, this transformation presents both opportunities and challenges, including standardisation and infrastructure deployment. This paper aims to explore the application prospects of 6G in these domains through comprehensive analysis, assess its anticipated impact, and examine future challenges and opportunities.

## 2. 6G as the Foundation for Next-Generation Positioning and Connectivity

### 2.1. Advantages and Capabilities of 6G Networks Compared to 5G

From the current perspective, the deployment of the fifth-generation cellular mobile network (5G) has progressed, aiming to establish a more flexible architecture to support low-latency requirements, higher bandwidth, and stronger data throughput capabilities.

However, some problems and limitations have gradually emerged. Due to the sharp increase in the number of Internet users and connected devices, the existing infrastructure and antenna density in the millimeter-wave frequency band are increasingly unable to meet the expected demands.

It is estimated that by the end of 2025, the number of Internet devices will reach 25 billion [1]. The new type of network must meet these increasingly growing demands for network performance. Therefore, 6G and subsequent network systems have also set brand-new goals:

The proposed data rate is a very high 1Tb/s, which is approximately 100 times higher than the data rate of 5G technology. An extremely ultra-reliable low-latency communication (eURLLC). It will be based on the integration of large-scale machine-type communication and 5G URLLC. The connection density is ten times that of 5G, meaning the device/area traffic capacity can reach up to 1 Gb/s/m. For resource-constrained devices, the energy efficiency is 10 to 100 times that of 5G, and the spectrum is 5 to 10 times that of 5G. Ubiquitous global network coverage. It is provided by the Space-Air-Ground Integrated Network (SAGIN), which consists of ground communication networks, air networks, and satellite networks [2].

## 3. The Connection and Technological Upgrade Between 6G Networks and Satellites

### 3.1. The Application and Performance Improvement of the Combination of 6G and Satellite Networks

Connecting 6G with satellite networks is a further expansion and upgrade based on the existing 5G network. By relying on satellite communication technology, the advantages of broad signal coverage and strong broadcasting ability can be fully realized. At present, countries around the world have begun to promote 6G research. Based on the performance indicators of communication networks, the study comprehensively considers the constructive roles of artificial intelligence and satellite communication in 6G networks. The future 6G satellite communication network will expand from the three major application scenarios of the 5G era - enhanced mobile Broadband (eMBB), ultra-reliable Low Latency Communication (uRLLC), and Massive Machine type communication (mMTC) - to enhanced mobile broadband (FeMBB) and highly reliable Low latency communication (ERLLC). Compared with 5G, the network energy efficiency of the five major application scenarios—eURLLC, wide-area high latency and high mobility communication (LDHMC), very large-scale machine type communication (umMTC), and ultra-low power communication (ELPC)—has been improved by 100 times. A factor of 5 to 10 has increased the spectral efficiency. The realization of these business and performance indicators relies on the empowerment of technologies such as artificial intelligence, cloud computing, distributed computing, and blockchain. Among these, artificial intelligence is the key technology that empowers the entire satellite and ground network.

### 3.2. Satellite Communication Architecture and the Evolution of Inter-satellite Links in the 6G Era

The architecture of satellite communication networks is an indispensable component of future 6G networks. The ground network and satellite network are integrated. The communication network covers the sea area, rural areas, transportation systems, base stations, and other ground infrastructure. In contrast, the satellite network includes satellites at different orbital altitudes, which can be classified into geosynchronous orbit satellites (GEO), medium Earth orbit satellites (MEO), and low Earth orbit satellites (LEO). Satellite networks offer wide-area coverage to meet the demands of 5G/6G networks. Various types of satellites undertake the functions of access nodes, forwarding nodes, and relay nodes, and support network management and control [3].

Another key technology for efficient satellite communication is the inter-satellite link (ISL) [4]. So far, the concept of ISL has undergone significant changes. Early satellite systems were highly dependent on ground stations, resulting in communication delays and limited coverage. In the 1970s, NASA's Tracking and Data Relay Satellite System (TDRSS) introduced relay satellites with direct communication capabilities, reducing reliance on ground stations and expanding the coverage of low Earth Orbit (LEO) satellites. By the 1990s, Iridium and Global Star satellite constellations adopted ISL technology to achieve global coverage and dynamic routing. ISL was initially based on radio frequency (RF) technology and has now developed into optical fiber ISL (OISL) [5]. These technological advancements have made the inter-satellite link (ISL) the cornerstone of the network topology (NTN), enabling flexible interstellar communication. However, the high deployment costs, the demand for precise beams, and the dynamic network management required for large-scale constellations still pose significant challenges. Therefore, future research directions will focus on areas such as adaptive beamforming, intelligent scheduling algorithms, interference suppression, and energy-saving design.

### 3.3. The Development Process of China's 5G Network towards 6 G

At present, global 6G technology research is still in the exploration and initial stage. The technical route is not yet clear, and the application scenarios have not been unified. It is currently in the stage of technology research, development, and scenario adaptation. The 6G network architecture is closely related to the technical route it adopts. Domestic research on 6G satellite communication technology routes and network architectures mainly includes: the air-ground-space integrated network architecture proposed by China Unicom, the "three-layer + four-sided" network architecture proposed by China Mobile, and the "air-space-land-sea" all-dimensional network architecture jointly proposed by domestic universities and enterprises [6]. At present, all the technical routes for achieving 6G proposed by international communication technology research and development institutions are still at the conceptual stage. Mainly focus on:

Global coverage and all-field application: Satellite communication and high-altitude platforms will play a significant role in profoundly impacting 6 G. The integration of satellite communication and ground networks will achieve global coverage and all-domain mobile networks, enabling users to access the network anytime and anywhere, ensuring service continuity.

Minimalist network: Ground communication protocols typically require multiple interactions, which do not align with the long delay characteristics of satellite links and cannot be directly transplanted into satellite communication networks. For scenarios such as large-scale Internet of Things services, these protocols need to be adaptively modified.

On-board processing: In the 6G era, satellites, based on supercomputing platforms, possess on-board processing capabilities and on-board caching capabilities. They support the deployment of on-board data processing units (DU), complete on-board base stations, on-board mobile edge computing (MEC), on-board content delivery networks (CDN), and even on-board lightweight core networks. Some protocols can be adaptively adjusted. However, these specific implementation still requires long-term research and practical exploration.

# 4. The Progress of the Impact of 6G Networks on the Internet of Vehicles

## 4.1. The Changes Brought by 6G to the Internet of Vehicles and Self-driving Cars

Vehicle communication technology has been around for many years. Still, the integration of artificial intelligence (AI) and machine learning (ML) with the upcoming 6G technology marks a significant shift in research directions and industrial structures concerning the understanding of connected and autonomous vehicles (CAVs). By applying artificial intelligence (AI) and machine learning (ML) technologies, vehicles will be able to make wiser decisions, predict and adapt to dynamic road conditions in real time, and simultaneously optimize on-board communication systems.

On this basis, the rapid development of 6G technology is expected to fundamentally reshape the functions of CAVs and drive the transportation system to achieve unprecedented progress [7]. 6G networks will offer ultra-high connectivity, ultra-reliable low-latency communication (URLLC), and seamless integration with the Internet of Things (IoT). These capabilities will enable self-driving cars to exchange and process massive amounts of data in real time, thereby achieving safer and more efficient navigation. Ultra-low latency ensures that Internet of Vehicles communication is completed almost instantly, enabling intelligent vehicles to respond to constantly changing road conditions and potential dangers with extraordinary speed and accuracy.

## 4.2. The Network Architecture of 6G Networks in the Internet of Vehicles

For 5G networks, China Mobile Research Institute and Huawei have proposed three 5G converged communication and sensing cellular network architectures in the literature, namely, distributed access network, centralized access network, and converged access network and core network [8]. The logical locations of perception are respectively affiliated with different access networks and core network elements. This architecture considers both communication and perception functions, but does not include computing functions.

In 6G networks, the China IMT-2030 (6G) Promotion Group has initially defined a three-layer 6G network architecture that integrates communication, perception, and computing, including the resource layer, capability layer, and application layer [9]. Beijing University of Posts and Telecommunications has proposed a more refined integrated network architecture for 6G communication, sensing, and computing. This architecture relies on the close coupling of communication, perception, and computing to achieve its integration. It supports vertical industry applications such as upper-level Internet of Vehicles and fully autonomous driving [10]. The leading hardware equipment of this architecture consists of four parts: core network cloud, integrated communication and sensing devices, intelligent edge devices, and distributed terminals. Among them, the core network cloud is responsible for providing flexible on-demand services, which are divided into two categories: business intelligent adaptation and resource intelligent adaptation. Integrated communication and sensing devices (base stations) and smart edge devices form an integrated network unit, achieving ubiquitous intelligent computing. By relying on future 6G ultra-high-speed and ultra-low latency wireless communication channels, they collaborate with artificial intelligence (AI) for endogenous computing. Integrated communication and sensing devices achieve this through protocol stack reconfiguration. Distributed terminals are divided into ordinary access terminals and synesthesia computing terminals. Among them, synesthesia computing terminals serve as access nodes with communication, perception, and computing capabilities. Super synesthesia computing terminals can run distributed learning algorithms such as federated learning.

## 5. Conclusion

The rapid development of 6G technology not only marks another breakthrough in the field of wireless communication but also serves as a key driving force for the transformation of navigation and autonomous driving systems. Compared with 5G, 6G has achieved an order of magnitude improvement in data transmission rate, ultra-low latency, and high connection density, and further integrates artificial intelligence, edge computing, and satellite communication networks to build a unified communication framework. These capabilities will effectively compensate for the shortcomings of the existing system, particularly in complex environments with unstable signals, limited coverage, and significant delays, ensuring the safe and efficient operation of vehicles.

For intelligent transportation and connected autonomous vehicles, 6G will provide a solid technical foundation for real-time data exchange, centimeter-level high-precision positioning, and seamless vehicle-to-everything (V2X) communication. These advancements will support safer decision-making, more efficient traffic management, and promote the implementation of new application scenarios such as collaborative driving, high-speed platooning, and dynamic traffic optimization. At the system level, the deep integration of 6G with satellite communication and inter-satellite links will become the core backbone of future intelligent transportation systems, achieving global coverage, reducing the predictability of accidents, and optimizing the travel experience within urban and rural areas.

However, the construction of a transportation ecosystem based on 6G still faces many challenges. High deployment costs, energy consumption issues, precise beam control, and large-scale constellation dynamic management remain key technical and economic obstacles. Meanwhile, issues such as network standardization, security, and data privacy need to be addressed urgently to ensure that the industry and regulatory authorities can reliably adopt and promote this new generation of technology.

In conclusion, 6G networks are expected to reshape the landscape of future navigation and autonomous driving through unprecedented connectivity, intelligence, and reliability. Its practical application will not only enhance road safety and traffic efficiency but also promote sustainable urban development and the innovation of global travel methods. However, to truly realize this vision, continuous research and international collaboration are still needed in areas such as technology, policy, and infrastructure construction. Only by overcoming these challenges can 6G fully unleash its vast potential in the field of intelligent transportation.

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